UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WASHINGTON, D. C.
H. H. BENNETT, CHIEF

ADVANCE REPORT

on the

SEDIMENTATION SURVEY OF LAKE CLINTON

CLINTON, OKLAHOMA

May 18 to June 14, 1938

By

Louis M. Glymph, Jr.

Sedimentation Studies
Office of Research
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In cooperation with
Oklahoma Agricultural Experiment Station
Stillwater, Oklahoma,
W. L. Blizzard, Director

(4466)

ABSTRACT

The sedimentation survey of Lake Clinton was made as part of a Nation-wide study of rates and causes of reservoir silting, especially as influenced by soil erosion and land use.

The lake was built during 1930 by the city of Clinton, Okla., for a water-supply reservoir. When completed it had a surface area of 336 acres and a capacity of 4,415 acre-feet. The reservoir receives drainage from an area of 22.47 square miles of typical western Oklahoma farm land. The major soil types of the drainage area have characteristics of the Dill and Vernon series, both of which occur on the Permian Quartermaster formation. About 69 percent of the drainage area is cultivated, the principal crops being cotton, small grain, grain sorghum, and corn; about 28 percent of the area is pasture; and about 3 percent is in homesteads and roads.

The survey revealed that 434 acre-feet of sediment had accumulated in the reservoir during the 7.4-year period between December 1930 and June 1938, resulting in an average annual storage loss of 1.33 percent. The sediment, ranging in texture from silt to coarse sand, is produced directly by accelerated soil erosion in the drainage area. It is estimated that about 97 percent of the land area has been affected to some extent by sheet erosion, 70 percent by wind erosion, and about 95 percent by gullying.

The relatively high rate of storage depletion strongly suggests that the application of measures for reducing the rate of sediment accumulation would be justified. It is concluded that the ultimate solution of the silting problem lies in the control of sediment at its source, and that a program of proper land use and soil conservation, including special treatment of certain nonagricultural areas, would materially reduce the annual rate of storage depletion.

INTRODUCTION

This report is one of a series of advance reports on reservoir-silting investigations made by the Sedimentation Division, Office of Research, Soil Conservation Service. Each reservoir survey is part of a Nation-wide study of the condition of American reservoirs with respect to storage reduction by silting. The ultimate objective of these studies is to determine rates and causes of reservoir silting in order to derive a practical index

to (1) the useful-life expectancy of existing or contemplated reservoirs, and (2) differences and changes in regional erosion conditions as influenced both by natural factors and by land use.

The sedimentation survey of Lake Clinton was made during the period May 18 to June 14, 1938. The survey party was composed of L. M. Glymph, Jr., party chief, Earl H. Moser, Jr., Robert M. Dill, and Ross E. Rogers. Two local men were employed during part of the survey period. A preliminary reconnaissance examination of the reservoir and its drainage area was made by Victor H. Jones in connection with flood-control studies in the Washita River drainage basin.

A reconnaissance map of the drainage basin, showing extent of erosion, land use, slopes, general soil-type boundaries, and areas of deposition, was made by the writer and Graham Renfro, junior soil technologist, Soil Conservation Service C. C. C. Camp, Okla. - 5, Clinton, Okla.

Moisture determinations and mechanical analyses of the sediment samples were made by H. J. Harper in the soils laboratory of the Oklahoma A. & M. College at Stillwater.

The Soil Conservation Service wishes to acknowledge the cooperation and assistance of the Clinton municipal government and its employees. Boats and material for marking survey points in the field, as well as data on water consumption, costs of the reservoir development and appurtenances, and other useful information were generously supplied.

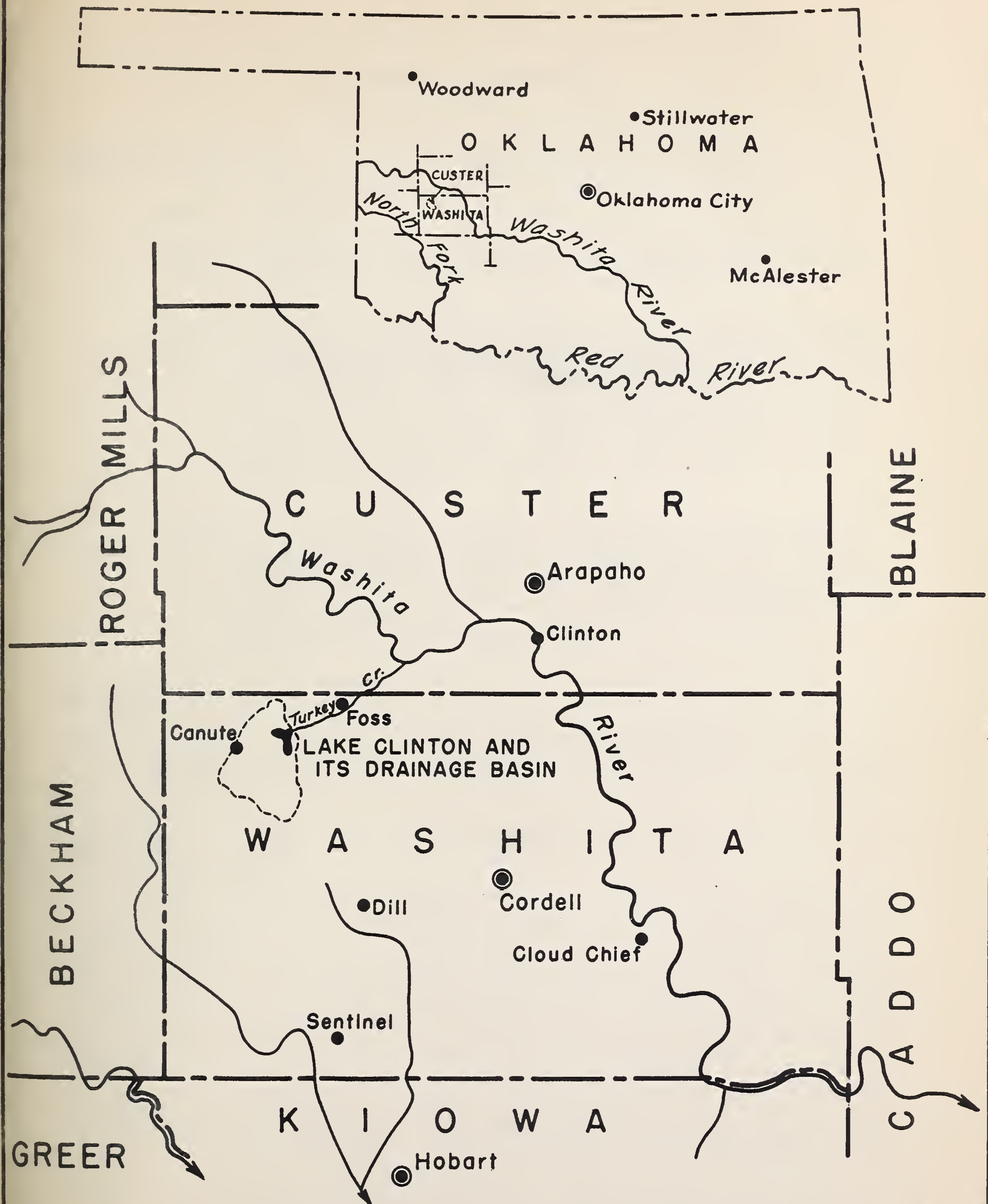

FIG. 1 - LOCATION AND GENERAL RELATIONSHIP OF LAKE CLINTON AND ITS DRAINAGE BASIN

Scale in Miles

0 5 10 15 20

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GENERAL INFORMATION

Location (fig. 1):

State: Oklahoma.

County: Washita. Secs. 9, 8, 7, 18, 17, 16, 28, and 21, T. 11 N., R. 19 W. (Turkey Creek township.)

Distance and direction from nearest city: The dam is about 1 mile north of United States Highway No. 66, 3 miles east of Canute, and about 16 miles west of Clinton. The main body of the reservoir lies north of the highway, but backwater of the Turkey Creek arm extends about three-fourths of a mile south of the highway bridge.

Drainage and backwater: Turkey Creek and its tributary Monument Creek. The dam extends across the Turkey Creek Valley just below the junction of Monument and Turkey Creeks. Turkey Creek joins the Washita River about 10 miles below the dam.

Ownership: City of Clinton.

Purpose served: Municipal water supply and recreation. The grounds around the reservoir are being developed for a public park.

Description of dam.

Lake Clinton is impounded by an earth-fill dam that has a length of 2,420 feet, a width at the top of 15 feet, a maximum base width of 305 feet, and a maximum height of 52 feet above stream bed. The top of the dam is 1,735 feet above sea level. The downstream face of the dam, which is sodded with bermuda grass, has a slope of 2:1 above elevation 1,700 feet and 4.5:1 below that level. The upstream slope of the dam is faced with stone slabs that are set on end in a clay blanket 2 feet thick and above spillway level are grouted in place with cement. The slope of the upstream face of the dam is 2:1 above elevation 1,730 feet; 2.5:1 between elevations 1,730 and 1,710 feet; and 3.5:1 below elevation 1,710 feet.

Over the stream channel the dam consists of a concrete structure that includes the spillway. The spillway crest begins about 650 feet from the south end of the dam and has a length of 268.5 feet, an elevation of 1,730 feet above sea level, and a maximum height of 47 feet above stream bed. The filtration plant is built into the north end of the spillway structure, part of it being in the recess beneath the spillway crest. A passageway

extends through the structure from one end to the other. The reservoir outlet works consist of three 14-inch slide gates, at elevations of 1,700, 1,710, and 1,720 feet above sea level, respectively, that open into intake pipes leading to the filter basins. Treated water flows by gravity through a pipe line from the filtration plant to storage tanks in Clinton.

The total original cost of the development, including the pipe line to Clinton, was approximately $600,000.

Historical record.

The dam was completed and storage began on December 21, 1930 and at the time of the survey the reservoir basin had been flooded and accumulating sediment for a period of 7.4 years. During the life of the lake the average seasonal draw-down of water below spillway crest has varied from 5 to 10 feet. The maximum draw-down occurred in May 1936, at which time the lake level fell 15 feet below the spillway. During the period of this maximum low water a heavy rain in the drainage area produced the maximum discharge to date. It is reported that 15 inches of water was passing over the spillway 3 hours after the rain began.

Length of lake:

	Miles
Monument Creek arm:	
Original	1.52
Present	1.48
Reduction by sedimentation	.04
Turkey Creek arm:	
Original	1.88
Present	1.66
Reduction by sedimentation	.22

Area of lake at spillway stage:

	Acres
Original	336
Present	333
Reduction by sedimentation	3

Storage capacity to spillway level:

	Acre-feet	
Original	4,415	(1,438,407,000 gals.)
Present	3,981	(1,297,009,800 gals.)
Reduction by sedimentation	434	(141,397,200 gals.)

General character of reservoir basin.

The reservoir basin, broadly V-shaped in outline (fig.8), may be considered in three parts: (1) A lower basin, between the dam and ranges R4-R5 and R3-R20, (2) Monument Creek arm, upstream from range R4-R5, and (3) Turkey Creek arm, upstream from range R3-R20.

The lower basin has an average width, exclusive of the embayments on its northwest and southeast sides, of about 2,200 feet, and at the time storage began this segment contained 44.7 percent of the total reservoir capacity. The submerged valley sides have an average slope of 4.3 percent. Turkey and Monument Creeks join between ranges R1-R2 and R3-R4. The cross sections of the two stream channels are essentially the same at their junction, their average width being 125 feet and their average depth 12 feet. The original gradient of the main channel from the dam to range R4-R5 on Monument Creek was 22.2 feet per mile; between the dam and range R3-R20 on Turkey Creek it was 27.5 feet per mile.

The Monument Creek arm extends westward from the lower basin for a distance of 1.2 miles, narrowing more or less gradually from 1,603 feet on range R4-R5 to 368 feet on R17-R18. Below R17-R18 the shore line is indented by many small tributary arms, and a short distance above this range open water is replaced by a maze of branching and rebranching ponded channels. In this arm the inundated valley walls have an average slope of about 4.5 percent, but the slopes vary locally from 2 to 8 percent. The channel of Monument Creek was about 160 feet wide and 10 feet deep when the basin was flooded, and its gradient above range R4-R5 was 30.6 feet per mile. The Monument Creek arm contained 31.4 percent of the original reservoir capacity.

Turkey Creek flows into the reservoir from the southwest, but the arm of the reservoir on this stream extends practically due north. This arm has a length of about 1.8 miles, of which nearly 1.5 miles lie above the forks. It decreases rather uniformly in width from 1,178 feet on range R3-R20 to 78 feet on range R51-R52, the only major irregularities in the shore line being the two side arms on the west shore. The submerged valley sides in this segment have average slopes of 6.6 percent but are somewhat steeper along the west side of the channel. The Turkey Creek channel, which follows a rather direct course through the submerged section, had a gradient of 23.8 feet per mile at the time storage began in 1930. The Turkey Creek arm originally contained 23.9 percent of the total reservoir capacity.

Measured from the dam to the head of backwater, the original gradient of Monument Creek was 29.0 feet per mile, and of Turkey Creek, 24.8 feet per mile.

Area of drainage basin: 23.0 square miles, as planimetered from aerial photographs.

General character of drainage basin.

Reconnaissance examination of watershed conditions.—The area draining into Lake Clinton is typical of a large part of the agricultural land in western Oklahoma. In order to study the relations of land conditions as to extent and rate of sedimentation, a reconnaissance examination of the drainage area was made and data on soil, slope, land use, degree of erosion, and depositional boundaries along streams were sketched on aerial photographs. Although contact prints on a scale of approximately 3 inches to the mile were used as a base for this mapping no attempt was made to carry out the investigation in detail. From the data assembled by the reconnaissance, a map was compiled from which the areas of the various features could be planimetered. This map, somewhat generalized, appears as figure 7, following page 19.

Geology.—Red sandstones and sandy clays and shales of the Permian Quartermaster formation underlie practically all the drainage area. The only exceptions are one or two small isolated areas of Cretaceous shell conglomerates and relatively inconspicuous areas of terrace sands and gravel. The Quartermaster formation is represented in the Lake Clinton drainage area by two distinct facies. Near the head of Turkey Creek a face of massive brownish-red sandstone about 75 feet thick is exposed along the west side of the channel. The weathering of this type of material produces a deep sandy soil, and on the basis of soil classes observed in the area it is estimated to underlie about 57 percent of the drainage basin. Thin beds of red silts, clays, and shales between layers of hard platy red sandstone and shale are exposed farther down Turkey Creek and at other points in the drainage area. This type of material weathers to form thin and relatively fine-textured red soils, the extent of which indicates that this facies of the Quartermaster underlies about 37 percent of the drainage area.

Topography and drainage.—The drainage area is part of a maturely dissected rolling plain that slopes northeastward to the Washita River. Its main streams have cut relatively deep and narrow V-shaped valleys that range in depth from about 20 feet near the reservoir to 125 feet near the headwaters of Turkey Creek. Erosion has progressed rapidly on the steep slopes adjoining the main streams and has formed areas of rough broken land that support only a scanty growth of grass. No extensive flood plains have developed along the streams.

Areas with rather gentle slope occupy a large part of the upland farthest from the streams, but gullies, tributary to the main streams, are rapidly advancing headward into the flat areas. The growth of these gullies is extending the area of rough broken land.

Figure 2.--Looking up the Turkey Creek arm of Lake Clinton, from top of hill just south of United States Highway No. 66. Note bars of sediment exposed with water level about 2 feet below spillway crest.

Figure 3.--A general view of the Turkey Creek arm, Lake Clinton, looking downstream from top of hill just south of United States Highway No. 66.

Soils.--The soils of the drainage area have not been classified by official mapping agencies, but five distinct types were recognized during the reconnaissance examination and tentatively identified as soils of four series that are known to be common in Washita County, in neighboring Beckham County, and in other parts of western Oklahoma.[1] The five soil types to which the soils in this area are believed to correspond and the relative proportion of the drainage area covered by each type are given in the following tabulation:

	Percent
Light red fine sandy loam (Dill)...........................	56.8
Reddish brown or bright red, very fine sandy loam (Vernon)	32.0
Red stony clay loam (Vernon)...............................	5.1
Reddish brown, fine sandy loam (Reinach)..................	3.1
Porous, brownish red, very fine sandy loam (Yahola)........	3.0
Total drainage area...	100.0

The approximate areas covered by each soil type are shown on the accompanying general erosion map (fig. 7).

Soil material similar to the Dill fine sandy loam is the most extensive single type in the drainage area. This type occurs principally on flat or gently rolling uplands. Its A horizon is usually a shallow layer of compact, structureless, light-red fine sandy loam. In areas of least erosion the A horizon is about 12 inches thick and grades into a brownish-red, gritty loam subsoil, or B horizon. The B horizon overlies the reddish-brown C horizon at a depth of about 30 inches, and the profile grades into parent material below depths of about 48 inches.

The loose, open soils of this type are highly susceptible to wind erosion when unprotected. Under most conditions, however, their porosity affords ready percolation of rain water so that they are somewhat less susceptible to water erosion.

Soils similar to the Vernon very fine sandy loam and stony clay loam are found in the steeper portions of the drainage basin, where the parent material is at or near the surface. Under most conditions the very fine sandy loam ranges from 6 to 10 inches in depth; it is structureless, reddish brown or bright red in color, and grades directly into the parent material. The stony clay loam occurs on slopes greater than 4 percent, and its depth usually does not exceed 3 inches. This type is also a red soil that grades directly into the parent materials.

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[1]The soils of Washita County have been mapped by the U. S. Bureau of Chemistry and Soils, but the report of this survey which gives official classification of soils in the Lake Clinton drainage area, had not been completed at the time of the Sedimentation Survey.

Owing to their relatively fine texture and shallow depth over hard, slowly permeable bases, these two soil types are subject to severe water erosion, but as a rule they are not seriously affected by wind erosion.

The soil material found along the streams in the zone of frequent overflow is similar in texture and location to the Yahola very fine sandy loam as mapped in neighboring counties. The topsoil is loose, porous, brownish red in color, and has a maximum depth of about 2 feet.

The soils developed along the streams, on gently undulating areas that are seldom overflowed, are similar in texture and location to the Reinach fine sandy loam. These soils are reddish brown on the surface but have lighter red subsoils that are very sandy and incoherent.

Slope.--Slope classes and the proportionate land area in each class are given in the following tabulation:

	Percent
0-3 percent (A slope)......................................	29.6
3-9 percent (B slope)......................................	62.6
9-12 percent (C slope).....................................	5.4
Over 12 percent (D slope)..................................	2.4
Total..	100.0

According to the reconnaissance data the steepest slopes are found on the soils tentatively identified with the Vernon series; 87 and 29 percent, respectively, of the very fine sandy loam and the stony clay loam have B slopes, whereas 13 and 71 percent of the same soils have greater than B slopes. About 59 percent of the area of Dill soil is on B slope, and 41 percent of this soil and all of the Yahola soils are on A slopes. Reinach soils are confined to A slopes.

Land use.--The extent of the land use classes in the drainage area is given in the following tabulation:

	Percent
Cropland...	69.0
Pasture..	28.4
Homesteads, roads, etc.....................................	2.6
Total..	100.0

During June 1938 the cultivated land was planted in cotton, small grain, grain sorghum, and corn; 34 percent of the area being in

cotton and corn, and 35 percent in small grain and sorghum. There is some variation each season in the area devoted to the several crops, but the amount of cultivated land probably remains about the same from year to year.

Erosion conditions.—Both water and wind erosion are active in varying degrees in the area. About 97 percent of the drainage basin is subject to sheet erosion and about 70 percent of the area has been affected to some extent by wind erosion. Occasional to frequent gullies, which range from a few inches to several feet in depth, have developed over about 95 percent of the area. As indicated by the above percentages all three types of erosion are frequently found in the same area in the drainage basin.

A generalized erosion map (fig. 7) has been prepared to show the approximate areas affected by each class of sheet erosion in the drainage basin, the approximate area of deposition along streams, and the sections of the drainage area in which severe sheet erosion and gullies have destroyed the major part of the land so far as present-day agriculture is concerned. Less severely gullied areas and areas of wind erosion are not shown separately. It may be stated, however, that the most extensive and harmful gullies occur in the areas of most severe sheet erosion, and that the most severe wind erosion is confined, generally, to the fine sandy loams that are tentatively identified as belonging to the Dill series. In assembling the erosion map several generalized classes of erosion were distinguished as follows:

Slight erosion.........	Less than 25 percent of topsoil removed.
Moderate erosion.......	25 to 75 percent of topsoil removed.
Severe erosion.........	More than 75 percent of topsoil removed.
Destroyed by erosion...	Severe sheet erosion and frequent gullies or severe sheet erosion and one or more large gullies that include more than 75 percent of the area.
Recent accumulation....	Deposition in areas along streams of material eroded from lands above.

No attempt was made to delineate the area and extent of colluvium, although deposits of this type are probably widespread.

A study of the map and the data, from which it was prepared, shows that moderate and severe erosion are the most extensive erosion classes, about 49.5 percent of the entire drainage area being affected by moderate erosion and 43.7 percent of the area being affected by severe erosion. Slight erosion and recent accumulation each cover about 3 percent of the area, while slightly less than 1 percent of the total drainage basin has been destroyed by erosion.

Soils tentatively identified with the Vernon series are the most severely eroded. About 76 percent of the area of both the very fine sandy loam and stony clay loam have suffered severe erosion,

whereas 27 percent and 19 percent, respectively, of the areas of Dill and Reinach soils have suffered erosion of the same intensity. Approximately 81, 68, and 24 percent, respectively, of the Reinach, Dill, and Vernon very fine sandy loam have undergone moderate erosion. All the area that has been destroyed by erosion is found on the stony clay loam identified as Vernon, and about 8 percent of the area of the same soil and 5 percent of the area of Dill very fine sandy loam has been affected by slight erosion. The entire area of recent accumulation is made up of soils tentatively identified as Yahola.

The proportionate extent of each slope class in the drainage basin, as determined by the reconnaissance examination, and the relation between slope and degree of erosion are shown in table 1.

Table 1.—Distribution of erosion in each slope class in the Lake Clinton drainage area

Degree of erosion	Slope class[1]				Entire drainage area
	(0-3)	(3-9)	(9-12)	(Over 12)	
	Percent	Percent	Percent	Percent	Percent
Slight...............	0.0	2.6	0.0	0.4	3.0
Moderate............	22.4	25.5	.4	1.2	49.5
Severe..............	1.1	37.6	5.0	.0	43.7
Destroyed...........	.0	.0	.0	.8	.8
Recent accumulation..	3.0	.0	.0	.0	3.0
Total.............	26.5	65.7	5.4	2.4	100.0

[1] A slopes 0 to 3 percent, B slopes 3 to 9 percent, C slopes 9 to 12 percent, and D slopes over 12 percent.

Figure 4.--Turkey Creek channel about 1 mile above the head of backwater of Lake Clinton, Note rock ledges in the stream bed and on the sloping bank.

Figure 5.--The head of a gully in the Lake Clinton area. Gullies of this type are common in the area and supply a large amount of sediment to the reservoir.

The proportionate extent of the types of erosion in each land use class is given in table 2.

Table 2.—Distribution of erosion in each land use class in the Lake Clinton drainage area

Degree of erosion	Cultivated land	Pasture	Homesteads, roads, etc.	Entire drainage area
	Percent	Percent	Percent	Percent
Slight.................	0.00	2.99	0.01	3.00
Moderate...............	39.3	8.3	1.9	49.5
Severe.................	29.52	13.55	.63	43.70
Destroyed..............	.00	.80	.00	.80
Recent accumulation.....	.22	2.78	.00	3.00
Total...............	69.04	28.42	2.54	100.00

It is shown by these data that a high percentage of the area of severe erosion is devoted to cultivated crops whereas all of the area of slight erosion and about one-sixth of the area of moderate erosion is used for pasture.

Mean annual rainfall.

No records of rainfall are kept at Lake Clinton but according to records of the United States Weather Bureau station at Cloud Chief, 25 miles southeast of the lake, the average annual rainfall is about 28 inches.

Draft on reservoir.

The reservoir is the sole water supply for the city of Clinton, Okla., which has a population of about 8,000. The peak of water consumption usually occurs during the months of July, August, and September, when the daily requirement is about 1,000,000 gallons, as compared with the yearly average of 800,000 gallons. During the summer months daily consumption occasionally rises to 2,000,000 gallons.

METHOD OF SURVEY

The original reservoir capacity and the volume of accumulated sediment were determined by the range method of survey developed by Eakin.[2] A triangulation-control system of 29 points was established from a base line 2,485 feet long chained along the dam. The spillway contour (elevation 1,730 feet above sea level) was mapped by plane table and telescopic alidade on a scale of 1 inch to 400 feet. The reservoir was divided into 51 segments by appropriately spaced ranges, along which measurements of water depth and sediment thickness were made. All range ends, cut-in stations, and other important survey points were marked for use in future resurveys by numbered iron pipe set in concrete.

Pre-lake soils underlying the sediment were easily recognized by their compactness and texture. Over most of the reservoir the old soil is noticeably more compact than the sediment, and in the lower basin it is coarser in texture. Near the head of backwater on the two arms the old soil is less sandy but more compact than the overlying deposits.

Seven samples of reservoir sediment were obtained from various parts of the lake. Four of the samples were taken with the 1 1/2-inch tubular sampler described in a previous report.[3] By this method of sampling, in which the sediment is collected in iron-pipe nipples and immediately sealed by airtight caps, it is usually possible to obtain relatively undisturbed samples for volume-weight determinations. Some of the sediment in Lake Clinton, however, was so soft and incoherent that it could not be retained in the sampler, making it necessary to take three of the samples with the spud and transfer them to the containers by hand.

SEDIMENT DEPOSITS

Character of Sediment

The locations, depth relations, and dry weight of the sediment samples are given in table 3.

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[2] Eakin, H. M. Silting of Reservoirs. U. S. Dept. Agr. Tech. Bul. 524:129-135, 1936. (Revised by Carl B. Brown, 1939.)

[3] Jones, V. H. Advance Report on the Sedimentation Survey of Lake Bracken, Galesburg, Illinois. U. S. Soil Conserv. Serv. SS-14:7, May 1937. (Mimeographed.)

Table 3.—Bottom samples from Lake Clinton

Sample No.	Location	Water depth	Sediment thickness	Penetration[1]	Dry weight per cubic foot
	Lower Basin	Feet	Feet	Feet	Pounds
1.....	Range R1-R2, 1,201 feet from R1......	33.0	4.5	2/	40.08
5.....	Range R4-R5, 711 feet from R5......	30.5	7.5	2/	57.31
4.....	Range R3-R20, 678 feet from R20.....	30.0	5.5	2/	39.21
	Monument Creek arm				
7.....	Range R9-R8, 674 feet from R9......	13.1	1.8	1.0	67.74
3.....	Range R15-R16, 332 feet from R16.....	3.4	10.0+	4.9	85.78
	Turkey Creek arm				
8.....	Range R25-R26, 449 feet from R25.....	16.0	4.5	2.0	61.74
6.....	Range R35-R36, 321 feet from R36.....	3.0	6.4	2.1	91.65

[1]Depth to which lower end of sampler penetrated sediment.
[2]Owing to the softness of the sediment, these samples had to be taken with the spud instead of the sampling tube and consequently represent a cross section of the deposit rather than a definite horizon. The volume weights of these samples could not be accurately determined.

The volume-weight determinations on samples 1, 4, and 5 are not considered as accurate as the others because they were disturbed in the sampling procedure. It is noteworthy, however, that the dry weight of all samples, except No. 4, increases from the dam toward the heads of both arms, in which respect there is also a general increase in the proportion of sand in all of the samples.

The mechanical compositions of the sediment samples are given in table 4.

Table 4.--Mechanical composition of sediment samples from Lake Clinton (determined by Bouyoucos hydrometer method)

Sample No.	Distance from dam	Sand	Silt	Clay
	Miles	Percent	Percent	Percent
Lower Basin:				
1....................	0.1	28.0	29.8	42.2
5....................	.3	27.6	31.8	40.6
4....................	.4	27.8	32.0	30.2
Monument Creek Arm:				
7....................	.7	77.8	22.0	.0
3....................	1.1	100.0	.0	.0
Turkey Creek Arm:				
8....................	.9	40.4	53.0	6.6
6....................	1.3	93.7	6.3	.0

The sediment in Lake Clinton is conspicuously laminated, especially in the two arms of the reservoir. The spud samples, however, which provide a complete cross section of the deposit, show that in general there is very little change in character of the sediment from top to bottom. An exception to this generalization occurs on a few of the ranges in the lower part of the lake, where a layer of very fine silty sand a foot or more in thickness was found between layers of silt and clay under the deepest water.

The color of the sediment ranges from chocolate brown to brownish red, the darker colors generally being found in the lower basin. The sandy material has about the same color as the soils in the drainage basin. Roots, grass stems, and some leaves are intermingled with the sediment in the two arms of the lake. A rather large

amount of such material has accumulated near the stream channel on range R5-R4, but it is absent in other parts of the lower basin.

Distribution of Sediment

The distribution of sediment in Lake Clinton is shown in table 5.

Table 5.—Distribution of storage capacity and sediment in Lake Clinton

Section	Capacity				Proportion of total sediment
	Original	June 1938	Reduction	Sediment	
	Acre-feet	Acre-feet	Percent	Acre-feet	Percent
Lower basin.........	1,973	1,845	6.49	128	29.50
Monument Creek arm..	1,385	1,233	10.97	152	35.02
Turkey Creek arm....	1,057	903	14.57	154	35.48
Total Reservoir...	4,415	3,981	9.83	434	100.00

In addition to the deposits that lie below spillway level, approximately 13 acre-feet of sediment has been deposited above spillway level on the Monument Creek arm and about 5 acre-feet has been deposited above spillway level on the Turkey Creek arm. This material, consisting of coarse sand deposited during flood periods, has become partly stabilized by the natural growth of willows and other vegetation. The obstruction created by this vegetation will tend to increase the quantity of sediment deposited above crest level by future floods.

The maximum depth of sediment was found to occur in, or near, the stream channels on almost all the ranges, the deposits gradually thinning toward the shore lines. The distribution of sediment on typical ranges is shown by figure 6.

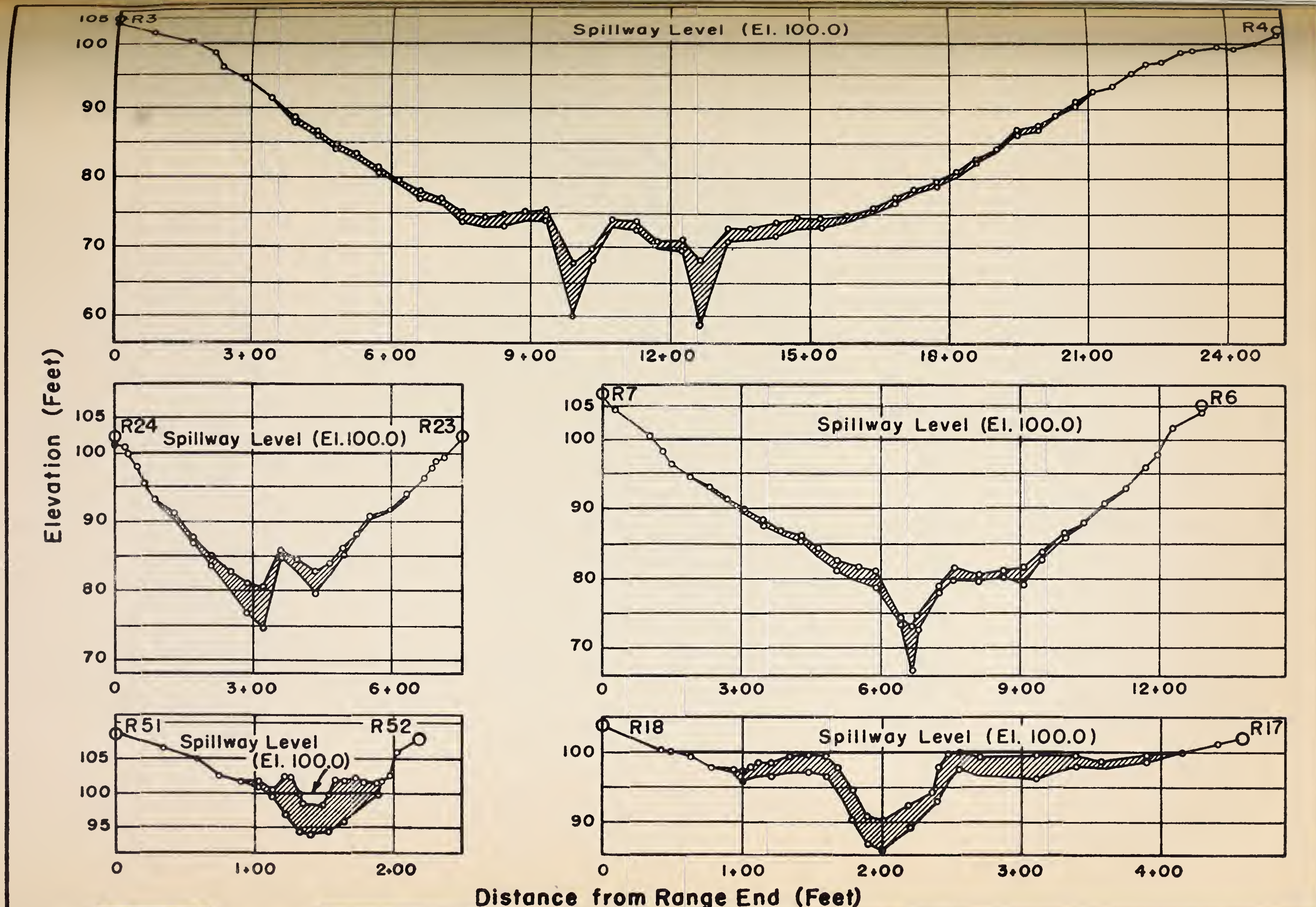

Fig. 6 - Representative Cross Sections of Lake Clinton.

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Sources of Sediment

As brought out in a preceding section of this report, water and wind erosion have been actively wearing away the surface soil of about 97 percent of the Lake Clinton drainage area. Part of the soil material moved from place by these processes, particularly by water erosion, is carried directly into the main streams and thence transported into the reservoir. Although it is not possible, with the data available, to calculate separately the exact quantities of material supplied by water and wind erosion or derived from the several areas characterized by various types of water erosion, the results of the reconnaissance examination of the drainage area afford a basis for certain deductions.

Most of the sediment that reaches the reservoir comes directly from areas undergoing (1) sheet erosion, (2) gully erosion, (3) stream-bank erosion, and (4) roadbed and road-ditch erosion. The relative importance of these several sources is discussed below.

It is estimated that more than 6,600 acre-feet of soil material has been moved from place on the area by sheet erosion alone since intensive cultivation began about 50 years ago. Of this amount an estimated 71 percent has been eroded on the soil type tentatively identified as Dill very fine sandy loam, about 23 percent on the Vernon very fine sandy loam, and about 3.5 and 2.5 percent, respectively, on the Reinach fine sandy loam and the Vernon stony clay loam. If it were assumed that the yearly rates of soil movement by sheet erosion are evidenced by the total amount of erosion to date, these estimates might be taken to indicate that the Dill very fine sandy loam is the most important single source of sediment. Field evidence does not confirm this, however, for the soil occupies gentle slopes generally well removed from the main drainage courses, and a large part of the output of erosional debris is deposited at the base of slopes and at other points near the source, and consequently, does not reach the main streams where it can be rapidly moved to the reservoir. Because of the greater slopes and the topographic position of the Vernon and Reinach soils, generally near the main drainage courses, the material eroded on them moves more rapidly toward the reservoir. It seems probable, therefore, that more sediment is derived by sheet erosion from these soils than from the Dill very fine sandy loam.

About 90 percent of the drainage area has been affected to some extent by gully erosion, which process is a very important factor in the production of sediment moved into Lake Clinton. The many sizable gullies in the drainage area (fig. 5) and the areas destroyed by erosion (fig. 7, following p.19) have undoubtedly supplied a large amount of the reservoir sediment. Roadbed and road-ditch erosion are closely related to gully erosion. Like many

of the gullies, roads and ditches feed erosional debris directly into the main streams, but they do not contribute a very large part of the sediment.

Stream-bank erosion and sheet erosion on the steep slopes adjoining the main streams supply an appreciable quantity of soil material to the reservoir each year (fig. 4).

Wind erosion probably contributes only a very small part of the annual sediment accumulation; however, drifts of wind-blown material frequently accumulate in drainage courses and are moved toward the reservoir by subsequent run-off. As wind erosion has affected about 70 percent of the drainage area, the resulting hummocks and irregularities in former relatively smooth and regular fields tend to concentrate run-off and thus facilitate the formation of small gullies. Wind erosion therefore probably has an important effect on the type and rate of water erosion.

CONCLUSIONS AND RECOMMENDATIONS

The detailed survey of Lake Clinton revealed a total accumulation of 434 acre-feet of sediment below spillway level, equal to an average annual storage loss of 1.33 percent. Theoretically, at this rate of storage depletion, the reservoir will be completely filled with sediment in 67.8 years. Actually, however, reserving a capacity equal to 1 year's draft (895 acre-feet at present rates of consumption) only about 52.6 years will be required for sedimentation to reduce the capacity to a volume equal to maximum service requirements. This calculation does not allow for the increase in the proportion of incoming sediment that will be bypassed through the reservoir as the storage capacity is progressively decreased, but this factor probably will not affect the general order of magnitude of the calculated remaining useful life. Such a rate of storage depletion strongly suggests that the application of measures to reduce erosion in the drainage area with consequent reduction of the silting rates may be doubly justified.

The construction of debris barriers and other engineering structures on the streams above the reservoir would reduce the rate of storage depletion temporarily, but the ultimate solution of the silting problem lies in the control of sediment at its source. The application of a coordinated program of proper land use and soil conservation practices, including special treatment of certain nonagricultural areas such as the gullies and the steep bare slopes that feed soil material directly into the main streams, would materially reduce the annual rate of storage depletion. In planning a program of land treatment specifically to reduce sediment production, further study is needed to determine the relative contributions from different erosion-type areas, so that the most

prolific sources of sediment could receive first treatment. It appears from the reconnaissance examination of watershed conditions that the steeper slopes and the large gullies are perhaps the most important sources of sediment.

The quantitative results of the detailed sedimentation survey of Lake Clinton are summarized in the tabulation on the following page.

Summary of data on Clinton Reservoir, Clinton, Okla.

	Quantity	Unit
Age[1]...................................	7.4	Years
Watershed area[2].........................	23.0	Sq. miles
Reservoir:		
Area at spillway stage:		
Original................................	336	Acres
At date of survey.......................	333	Acres
Storage capacity to spillway level:		
Original................................	4,415	Acre-feet
At date of survey.......................	3,981	Acre-feet
Capacity per sq. mile of drainage area:[2]		
Original................................	191.96	Acre-feet
At date of survey.......................	173.09	Acre-feet
Sedimentation:		
Total sediment[3].........................	434	Acre-feet
Average annual accumulation:		
From entire drainage area...............	58.6	Acre-feet
Per 100 sq. miles of drainage area[4].....	261	Acre-feet
Per acre of drainage area:[4]		
By volume.............................	177.57	Cubic feet
By weight[5]...........................	5.63	Tons
Depletion of storage:		
Loss of original capacity:		
Per year................................	1.33	Percent
To date of survey.......................	9.83	Percent

[1]Storage began December 21, 1930; date of survey May 18-June 14, 1938.

[2]Including area of lake.

[3]Excluding 18.83 acre-feet deposited above spillway crest, 13.82 acre-feet on the Monument Creek arm, and 5.01 acre-feet on the Turkey Creek arm.

[4]Excluding area of lake.

[5]Based on average dry weight of 63.36 pounds per cubic foot of sediment, as determined from 7 samples.

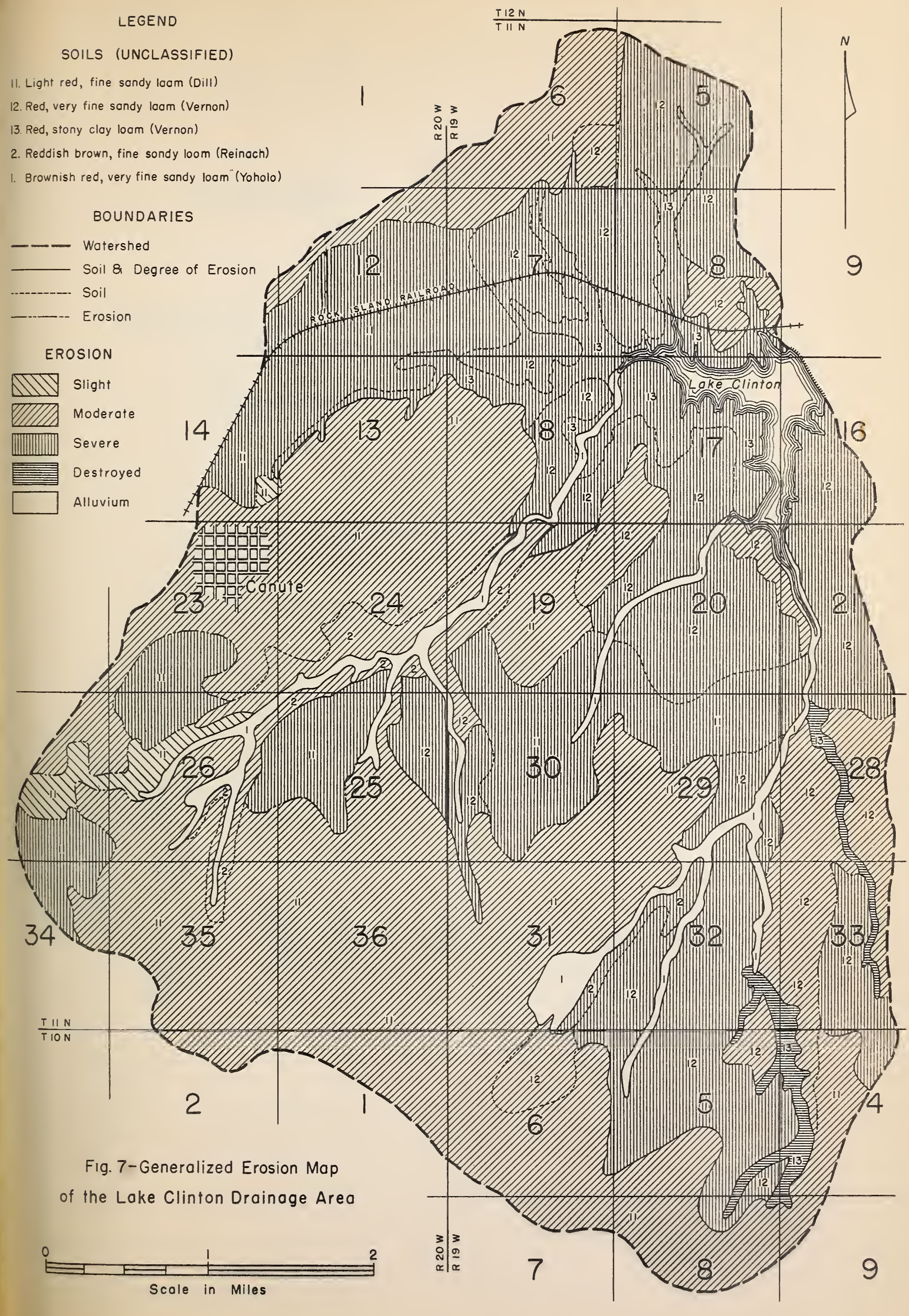
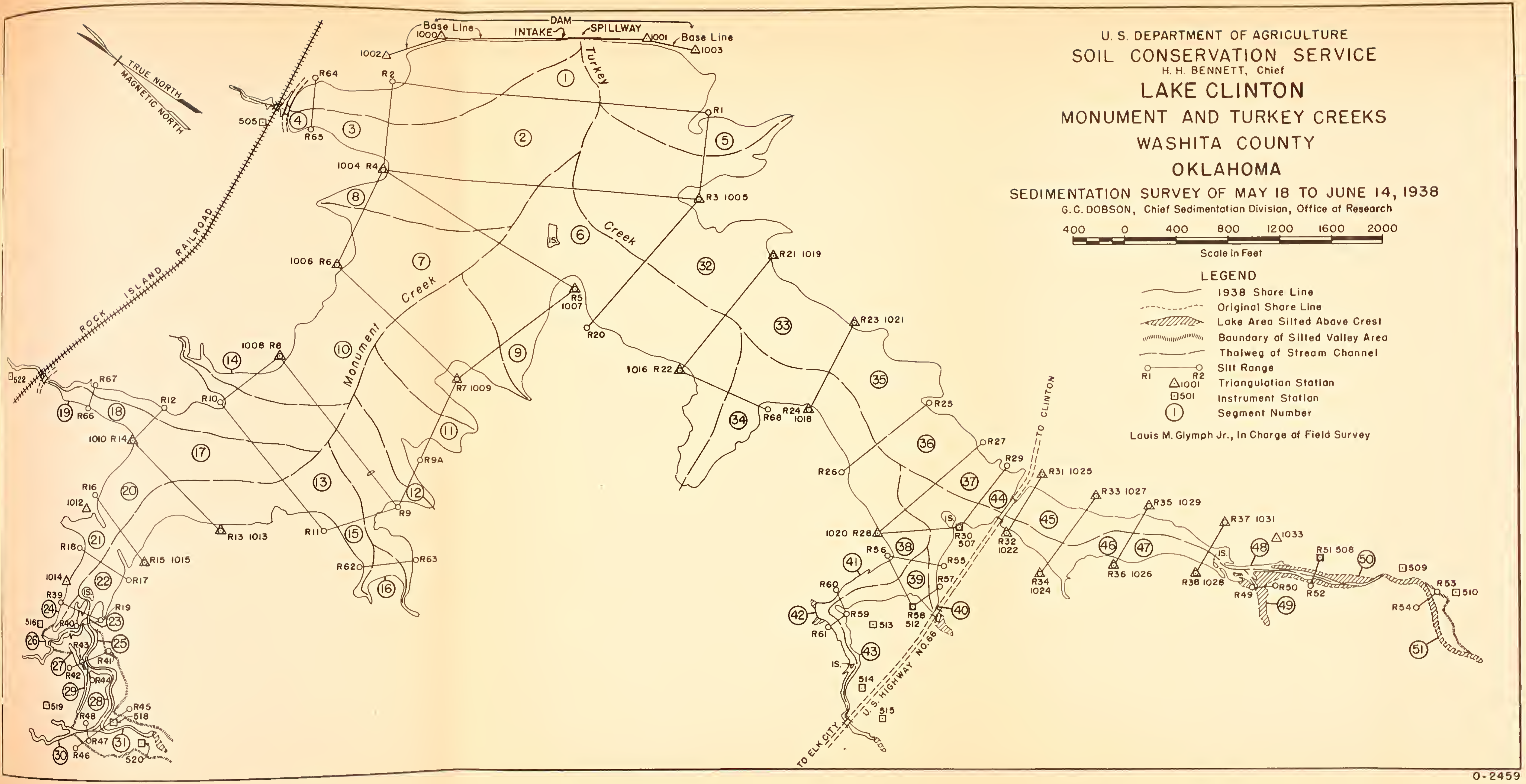


Fig. 7-Generalized Erosion Map of the Lake Clinton Drainage Area

Figure 8



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